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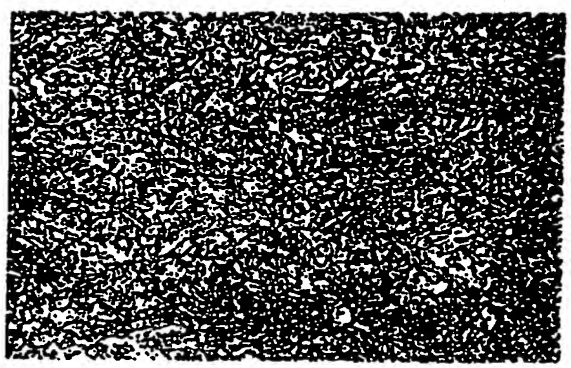

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(57) Abstract

A high performance weathering steel having a minimum yield strength of 70–75 ksi and a yield/tensile ratio less than about 85 is produced from a steel composition consisting essentially, in weight percent, of about: carbon 0.08–0.12 %; manganese 0.80–1.35 %; silicon 0.30–0.65 %; molybdenum 0.08–0.25 %; vanadium 0.06–0.14 %; copper 0.20–0.40 %; nickel 0.50 % max.; chromium 0.40–0.70 %; iron, balance except for incidental impurities; heating the steel to a hot rolling temperature, rolling the steel to a thickness about 2 times the final desired thickness, air–cooling the steel to a temperature of about 1800–1850 °F, recrystallize control rolling the steel with finish rolling at a temperature of about 1700–1750 °F, then water–cooling the steel to about 900–1200 °F, then air–cooling the steel to ambient temperature, to produce sections up to 90 feet or more, without further heat treatment.

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THERMOMECHANICALLY CONTROLLED PROCESSED HIGH STRENGTH WEATHERING STEEL WITH LOW YIELD/TENSILE RATIO

BACKGROUND

Field of the Invention

This invention relates to high strength, high performance, weathering plate steels with high yield strength, at least 70 ksi, preferably at least 75 ksi, and low yield strength-to-tensile strength ratio, and particularly, to thermomechanically controlled processing (TMCP) methods of manufacturing plates of such steels in long, e.g. about 90 to 120 foot, sections up to about 2 1/2 inches thick, without heat treatment such as quenching and tempering. Articles so made are especially useful for the fabrication of bridges and other constructional applications.

Prior Art

U.S. Patent No. 2,586,042 discloses a low-alloy, high-yield strength (50 ksi) fabricable steel with superior resistance to atmospheric corrosion in thicknesses to about 1/2 inch [COR-TEN (later COR-TEN A); a registered trademark of U.S.Steel), ASTM A242], of medium carbon content (0.10-0.20 wt.%) and containing Mn, Ni, Cr, Mo (0.40-0.60 wt.%), V (0.03-0.10 wt.%), B, Si and Cu. A later modification (U.S. Patent No. 2,858,206)--COR-TEN B (ASTM A588)--containing 0.12 wt.%C, with Mn, Si, Cu, Cr, Mo (0.15-0.45 wt.%), V (0.03-0.078 wt.%), Ti and B, was introduced to fill the need for a 50 ksi yield strength steel in plate thicknesses through about 4 inches. These two steels have been extensively employed in a variety

of constructional applications such as railroad cars, bridges and exposed building framework elements.

Further improvements were made to these steels, including a relatively inexpensive steel with a minimum yield strength of 70 ksi, after quenching and tempering, in plate thicknesses to about 4 inches. "Mechanical Properties and Weldability of a 70 Ksi Minimum Yield Strength Steel for Bridge Applications," (COR-TEN B-QT 70; ASTM A852 or A709 Grade 70W), U.S. Steel Technical Center Bulletin, April 30, 1985. Such steels generally contained about 0.16-0.20 wt.% C, and such thick plates required a minimum preheat and interpass temperature of about 200-400°F.

A recent publication by Nippon Steel Corporation, Development of High Performance Steels for Structures, K. Ichise et al., presents an overview of high performance steels and their manufacture, including use of the thermomechanical control processing (TMCP).

Despite the existence of such prior art steels, the need still exists for a steel having a minimum yield strength of 70 ksi with low yield/tensile ratio and producible in long, e.g. 90 foot, sections for, particularly, bridge and ship construction, and without the need for preheating or quenching and tempering (facilities for such heat treatments of such long sections do not exist; they are limited to about 50-55 foot lengths). Such long sections are of further advantage in reducing the number of splice welds of shorter sections and thus reduce costs and enhance appearance and performance of the fabricated structure.

SUMMARY OF THE INVENTION

The invention provides a steel having a composition as follows:

Table I

Element	Weight Percent
carbon	0.08-0.12 preferably less than 0.10
manganese	0.80-1.35
silicon	0.30-0.65
molybdenum	0.08-0.25, preferably about 0.12 to 0.20
vanadium	0.06-0.14
copper	0.20-0.40
nickel	0.50 max.
chromium	0.40-0.70
iron	balance, except for incidental steelmaking impurities,

which steel is reheated, e.g. at a temperature of about 2150°F, hot rolled, e.g. to a thickness about 2 times the final desired thickness, air-cooled, e.g. to a temperature of about 1800-1850°F, recrystallize control rolled (RCR) with finish rolling at a temperature near or slightly above the recrystallization-stop temperature, usually about 1700-1750°F, then water-cooled to about 900-1200°F, preferably 900-1100°F, especially about 1100°F, for example at a rate of about 12-18 °F per second for 1 1/2-inch-thick plates, then air-cooled to ambient temperature (interrupted accelerated cooling--IAC). In this manner, there can be produced long sections, up to 90 feet or more, wherein the steel has a minimum yield strength of 70-75 ksi and a low yield/tensile strength ratio, e.g. less than 0.8-0.9 (85-90%), preferably less than 80%, without further heat treatment.

When so processed the Table I steels have a fine grain dual microstructure comprising primarily acicular ferrite and bainite (possibly with some minor amounts of martensite), and are essentially free of pearlite and blocky proeutectoid ferrite.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the variation of yield strength and toughness (Charpy V-Notch test) versus molybdenum content in ASTM A852 or A709 Grade 70W-type steel (COR-TEN B-QT 70).

Fig. 2 is a photomicrograph showing the fine grain, largely acicular ferrite/bainite structure of the steels of the invention when processed by the RCR/IAC method.

DESCRIPTION OF PREFERRED EMBODIMENTS

Six five-hundred pound laboratory heats of the following steel compositions were made according to Table II:

Table II

Heat No.	Composition, Weight Percent													
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Ti	Al	N
8016	0.090	1.20	0.019	0.007	0.44	0.29	0.25	0.60	0.007	0.031	0.021	--	0.027	0.005
8021	0.094	1.19	0.018	0.007	0.43	0.27	0.26	0.60	0.008	0.088	--	0.016	0.027	0.010
8061	0.090	1.20	0.014	0.005	0.46	0.30	0.25	0.60	0.008	0.072	--	--	0.027	0.006
8010	0.091	1.19	0.013	0.004	0.44	0.30	0.24	0.59	0.057	0.066	--	--	0.025	0.005
8011	0.096	1.21	0.015	0.004	0.43	0.29	0.26	0.61	0.130	0.060	--	--	0.026	0.005
8062	0.091	1.20	0.015	0.005	0.44	0.30	0.25	0.60	0.200	0.070	--	--	0.029	0.006

Ingots of the steels of Table II were soaked at 2150°F. All steels then were rolled to 1.5 inch thickness. One plate of steel 8016 was hot rolled to final thickness and finished at about 1950°F, then air cooled. Three other plates were controlled rolled to 2.5 times the final thickness, air-cooled to about 1600°F, then rolled to the final thickness, finishing at about 1500°F. One of these plates was then air cooled; the other two were interrupted-accelerated cooled, one to 900°F, the other to 1100°F. Three plates of steel 8021 were rolled to 2.5 times final thickness, air-cooled to 1800°F, then recrystallize controlled-rolled to final thickness with a finishing temperature of about 1725°F. One plate was then air cooled and the other two plates were interrupted-accelerated cooled, one to 900°F, the other to 1100°F. Two plates of each of heat nos. 8010 and 8011 were rolled to 2.5 times the final thickness, air-cooled to 1800°F, then recrystallize controlled-rolled to final thickness, finishing at about 1725°F, then interrupted-accelerated cooled, two plates to 1100°F and two to 900°F. Two plates of each of heat nos. 8061 and 8062 were rolled to 2.5 times the final thickness, air-cooled to 1800°F, then recrystallize controlled-rolled to final thickness, finishing at about 1725°F, then interrupted-accelerated cooled, two plates to 1100°F and two to 900°F.

Properties of these steels are given in the following tables, showing the effect of interrupted-accelerated cooling (IAC) on the transverse quarter-thickness strength and toughness

properties of 1.5 inch thick, low-carbon COR-TEN B plate with varying contents of molybdenum and vanadium.

Table III
Heat No. 8016 (0.007% Mo; 0.031% V; 0.021% Cb)

Condition	Tensile[1] Yield Strength, ksi[2]	Tensile Strength, ksi	Yield/Tensile Ratio	Charpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Microstructure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Hot rolled	77.1	92.3	0.84	30[15]	50[30]	105[100]	11.5
Controlled -Rolled (CCR)	81.5	94.5	0.87	28[22]	45[40]	80[100]	12.5
Conventional Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	65.8	97.4	0.68	8[5]	17[20]	28[60]	10.0
IAC to 900°F	70.4	112.0	0.63	21[20]	29[45]	49[100]	10.5
Conventional Controlled-Rolled, Interrupted-Accelerated Cooled[3] and Tempered (1175°F)							
IAC to 1100°F	74.2	92.4	0.80	9[10]	22[40]	64[95]	11.0
IAC to 900°F	84.8	100.4	0.84	21[60]	39[85]	49[100]	10.5

(1) Average results.
(2) 0.2% offset.
(3) Water-spray-cooled to a midthickness temperature and air-cooled.

Table IV
Heat No. 8021 (0.008% Mo; 0.088% V; 0.016% Ti)

Condition	Tensile[1] Yield Strength, ksi [2]	Tensile Strength, ksi	Yield/Tensile Ratio	Charpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Microstructure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Hot rolled	82.3	97.0	0.85	26[10]	42[25]	81[70]	11.5
Controlled -Rolled (CCR)	85.4	100.2	0.85	24[10]	38[20]	73[60]	11.5
Recrystallize-Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	61.4	96.3	0.64	24[10]	33[10]	72[62]	10.5
IAC to 900°F	73.1	105.1	0.70	23[7]	36[10]	70[55]	10.5
Recrystallize-Controlled-Rolled, Interrupted-Accelerated Cooled[3] and Tempered (1175°F)							
IAC to 1100°F	78.1	96.0	0.81	11[5]	21[10]	53[50]	10.5
IAC to 900°F	83.5	99.2	0.84	11[5]	22[10]	54[45]	10.5

[1] Average results.
[2] 0.2% offset.
[3] Water-spray-cooled to a midthickness temperature and air-cooled.

Table V
Heat No. 8010 (0.057% Mo; 0.066% V)

Condition	Tensile[1] Yield Strength, ksi[2]	Tensile Strength, ksi	Yield/Tensile Ratio	Charpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Microstructure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Controlled -Rolled (RCR)	85.4	100.3	0.85	28[10]	50[15]	95[47]	10.5
Recrystallize-Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	65.4	99.6	0.66	40[12]	40[10]	60[30]	10.5
IAC to 900°F	71.3	102.8	0.69	40[10]	48[15]	91[47]	11.5
Recrystallize-Controlled-Rolled, Interrupted-Accelerated Cooled[3] and Tempered (1175°F)							
IAC to 1100°F	77.5	95.6	0.81	55[25]	50[15]	64[30]	10.5
IAC to 900°F	84.3	100.7	0.84	30[10]	41[12]	73[50]	11.0

[1] Average results
[2] 0.2% offset
[3] Water-spray-cooled to a midthickness temperature and air-cooled

Table VI
Heat No. 8011 (0.13% Mo; 0.060% V)

Condition	Tensile[1] Yield Strength, ksi[2]	Tensile Strength, ksi	Yield/Tensile Ratio	Charpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Micro-structure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Controlled -Rolled (RCR)	88.1	102.7	0.86	33[10]	54[13]	88[45]	11.0
Recrystallize-Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	76.4	104.0	0.73	32[6]	56[17]	109[55]	11.5
IAC to 900°F	79.5	105.8	0.75	25[5]	66[20]	104[55]	11.5
Recrystallize-Controlled-Rolled, Interrupted-Accelerated Cooled[3] and Tempered (1175°F)							
IAC to 1100°F	84.4	102.0	0.83	50[15]	59[17]	72[31]	10.5
IAC to 900°F	88.8	105.8	0.84	34[6]	54[15]	64[35]	11.0

(1) Average results
(2) 0.2% offset
(3) Water-spray-cooled to a midthickness temperature and air-cooled

Table VII

Heat No. 8061 (0.008% Mo; 0.072% V)

Condition	Yield Strength, ksi [2]	Tensile[1] Tensile Strength, ksi	Tensile[1] Yield/Tensile Ratio	Carpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Microstructure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Controlled -Rolled (RCR)	76.5	91.6	0.83	59[17]	77[30]	107[75]	9.5
Recrystallize-Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	66.5	97.9	0.68	28[12]	42[25]	77[60]	9.5
IAC to 900°F	76.6	102.2	0.75	22[10]	44[27]	81[65]	10.0

Table VIII

Heat No. 8062 (0.20% Mo; 0.070% V)

Condition	Yield Strength, ksi [2]	Tensile[1] Tensile Strength, ksi	Tensile[1] Yield/Tensile Ratio	Charpy V-Notch Impact[1] Energy, ft-lb [% Shear] -40°F	0°F	+72°F	Microstructure Grain Size (ASTM No.)
Reheat-Quench and Tempered (1175°F)							
Controlled -Rolled (RCR)	90.8	103.7	0.87	66[20]	75[27]	88[57]	11.0
Recrystallize-Controlled-Rolled and Interrupted-Accelerated Cooled[3]							
IAC to 1100°F	81.3	109.8	0.74	38[20]	55[35]	89[67]	11.5
IAC to 900°F	81.3	117.5	0.69	35[18]	44[30]	94[70]	12.0

(1) Average results
(2) 0.2% offset
(3) Water-spray-cooled to a midthickness temperature and air-cooled

From Table III, directed to the 0.007% Mo, 0.031% V, 0.021% Cb steel, it can be seen that high yield strength, above 75 ksi, and low yield/tensile ratio were obtained in the quenched and tempered steels, with both rolling practices. However, the conventional controlled-rolled and IAC steels reached only 65.8 ksi yield strength when cooled to 1100°F, and 70.4 when cooled to 900°F. Tempering after the latter rolling practices increased the yield strength to 74.2 ksi at a cooling-stop temperature of 1100°F and 84.8 ksi at a cooling-stop temperature of 900°F.

Similar results for the quench and tempered processing are shown in Table IV for the 0.008% Mo, 0.088% V, 0.016 Ti steel. RCR/IAC processing gave a yield strength of only 61.4 ksi on cooling to 1100°F, and 73.1 ksi on cooling to 900°F. Tempering such processed steel raised the yield strength to 78.1 ksi on cooling to 1100°F and 83.5 ksi on cooling to 900°F.

Similar results were obtained with the 0.057% Mo, 0.066% V steel, as shown in Table V.

As shown in Table VII, RCR/IAC processing of the 0.008% Mo, 0.072% V steel, gave an acceptably high yield strength (76.6 ksi) upon cooling to 900°F, but only 66.5 ksi when the steel was cooled to 1100°F.

From Tables VI and VIII, setting forth the properties of steel heat Nos. 8011 and 8062, containing, respectively, 0.13% and 0.20% Mo, it is seen that these steels, when processed by the RCR/IAC procedure, without further heat treatment, each showed a minimum yield strength of greater than 75 ksi when IAC cooled to either 1100°F or to 900°F, and each had a low yield-to-

tensile strength ratio, i.e. 0.75 or less. In each such case, the steel exhibited high impact strength, CVN, ft.-lbs. In contrast, steels 8021 and 8061, each containing 0.008% Mo, when similarly processed, showed a lower yield strength: steel 8021 having 61.4 ksi yield strength when cooled to 1100°F and 73.1 ksi when cooled to 900°F, and steel 8061 showing a yield strength of only 66.5 ksi when cooled to 1100°F, although when cooled to 900°F it had a yield strength of 76.6 ksi. In case of each of the latter steels, the steel showed a lower impact strength than the higher Mo steels. Similarly, steel 8010, containing 0.057% Mo, when similarly processed, showed a yield strength of 65.4 ksi when cooled to 1100°F and 71.3 when cooled to 900°F, and it, too, had lower impact strength.

Although steels 8016, 8021 and 8010, when processed by RCR/IAC and tempered, gave high yield strength and low yield/tensile ratio, conventional tempering is not practical for long products, such as bridge girders, since existing tempering facilities will not accommodate such great lengths.

The effect of Mo content on yield strength and impact strength of these steels, containing at least about 0.06 wt.% V, is shown graphically in Fig. 1, from which it is seen that at least about 0.08-0.10 wt.% Mo is required to assure a minimum yield strength of 70 ksi when the steel is IAC cooled to 900°F and about 0.12% Mo is required to assure a minimum yield strength of 70 ksi when the steel is IAC cooled to 1100°F. Also, at about 0.08% Mo, the CVN impact strength resulting from both 900 and 1100° F cooling begins a sharp increase which continues

and approaches each other at about 0.13% Mo, after which point, the CVN begins to decrease, the 900 and 1100°F cooling curves for CVN impact strength becoming equal at about 0.20% Mo, at which point the yield strength has become essentially constant at about 80 ksi for both the 900 and the 1100°F cooling curves. Accordingly, Mo is limited to about 0.08% to about 0.25%, preferably to about 0.10% to about 0.20%, and especially about 0.12% to about 0.20%.

For commercial production, IAC cooling to about 1100°F is preferred over lower temperatures because, at such higher temperature, as compared, e.g. to a temperature of 900-1050°F, the steel is easier to flatten and level. Moreover, at temperatures lower than about 900°F, the steel tends to form more bainite, possibly decreasing impact properties. At temperatures above about 1200°F, e.g. about 1300°F, the needed fine grain structure is not obtained, with accompanying decrease of strength properties.

The photomicrograph of Fig. 2 shows the essentially acicular ferrite and bainite fine grain microstructure of the steels processed in accordance with the invention. Increasing Mo content upwardly of about 0.2%, and especially above about 0.25 wt.%, results in the formation of excessive amounts of martensite with accompanying decrease of steel properties.

The above steels, when processed by the RCR/IAC method, as described, should possess good weldability, suiting them for constructional fabrication applications.

The achievement of a uniform minimum yield strength of 70-75 ksi, together with low yield/tensile ratio and high impact strength, without the need for further heat treatment, after RCR/IAC processing, permits, for the first time, the production of long, e.g. up to 90 feet or greater, sections of steel products up to about 2 1/2 inches thick, such as plates, tubes, and fabricated shapes, for bridge, ship and other constructional applications.

With conventional quenching and tempering, the low-carbon steels of the invention can be produced in section thicknesses up to about 4 inches and having high yield strength (at least 70 ksi) and relatively low yield/tensile ratio--useful in applications in which very long sections are not needed. Such steels should exhibit better weldability than the current, higher carbon A852 quenched and tempered steel.

What is claimed is:

1. A method of producing high strength weathering constructional steels in elongated sections up to about 90 to 120 feet in length and up to about 2 1/2 inches thick, comprising:

a) providing a steel composition consisting essentially of about

Element	Weight Percent
carbon	0.08-0.12
manganese	0.80-1.35
silicon	0.30-0.65
molybdenum	0.08-0.25
vanadium	0.06-0.14
copper	0.20-0.40
nickel	0.50 max.
chromium	0.40-0.70
iron	balance except for incidental impurities;

b) heating the steel to a hot rolling temperature;

c) hot rolling the steel to a thickness less than the final desired thickness;

d) air-cooling the steel to a temperature of about 1800-1850°F;

e) recrystallize control rolling the steel to final thickness with finish rolling at a temperature of about 1700-1750°F;

f) water-cooling the steel to a temperature of about 900-1200°F, and

g) air-cooling the steel to ambient temperature, without further heat treatment,

whereby the steel has a fine grain dual microstructure of acicular ferrite and bainite essentially free of pearlite and

exhibits a minimum yield strength of 70 ksi and a yield-to-tensile strength ratio less than about about 85.

2. A method according to claim 1, wherein the maximum molybdenum content is about 0.20%.

3. A method according to claim 2, wherein the lower limit of molybdenum content is about 0.10%.

4. A method according to claim 1, wherein the molybdenum content is about 0.12 to about 0.20%, the minimum yield strength is 75 ksi and the yield/tensile ratio is under 80 when the rolled steel is water cooled to a temperature in the range of about 900-1200°F.

5. A method according to one of claims 1-4, wherein the maximum carbon content of the steel is about 0.10%.

6. A method according to one of claims 1-4, wherein the steel is initially heated to a temperature of at least about 2150°F, hot rolled to a thickness of about 2 to 2 1/2 times the desired final thickness, recrystallize control rolled to final thickness and, after rolling, is water-cooled, at a rate of about 12 to about 18°F per second for 1 1/2-inch thick plates, to a temperature of about 1100-1150°F.

7. A method according to one of claims 1-4, wherein the rolled article is up to about 50 feet in length and up to about 4 inches in thickness, excluding the steps of recrystallize control rolling and interrupted accelerated cooling and further including the step of quenching and tempering the article to provide a yield strength of at least 70 ksi and a yield/tensile strength ratio below about 90.

8. A steel article made in accordance with the method of one of claims 1-4.

9. A steel article made in accordance with the method of one of claims 1-4 and wherein the steel has been initially heated to a temperature of at least about 2150°F and, after recrystallize control rolling, has been water-cooled to a temperature of about 1100-1150°F.

10. A steel article made in accordance with one of claims 1-4, wherein the article is up to about 50 feet in length and up to about 4 inches thick, and wherein the steps of recrystallize control rolling and interrupted accelerated cooling have been omitted and wherein the article has been quenched and tempered and has a yield strength of at least 70 ksi and a yield/tensile strength ratio less than about 90.

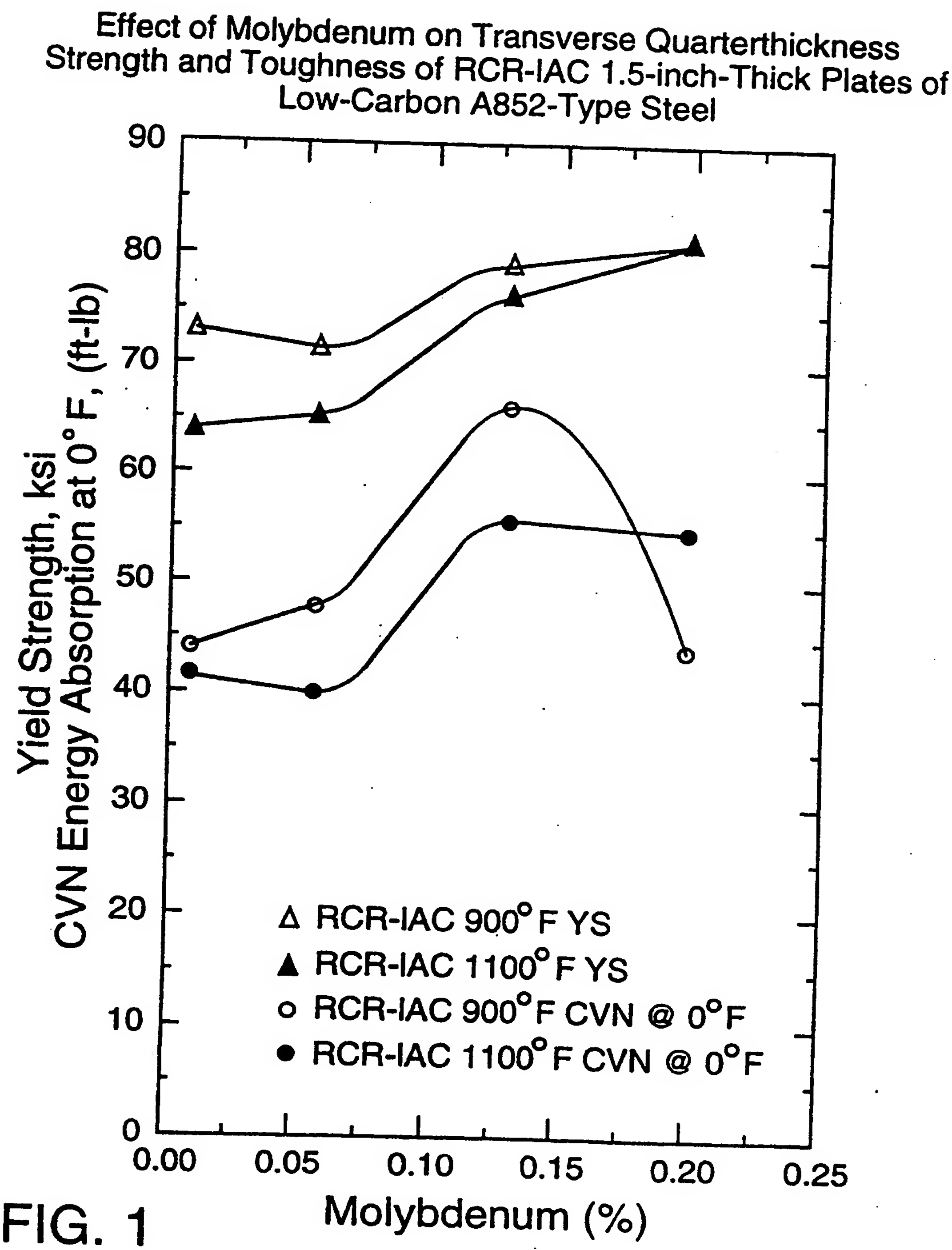
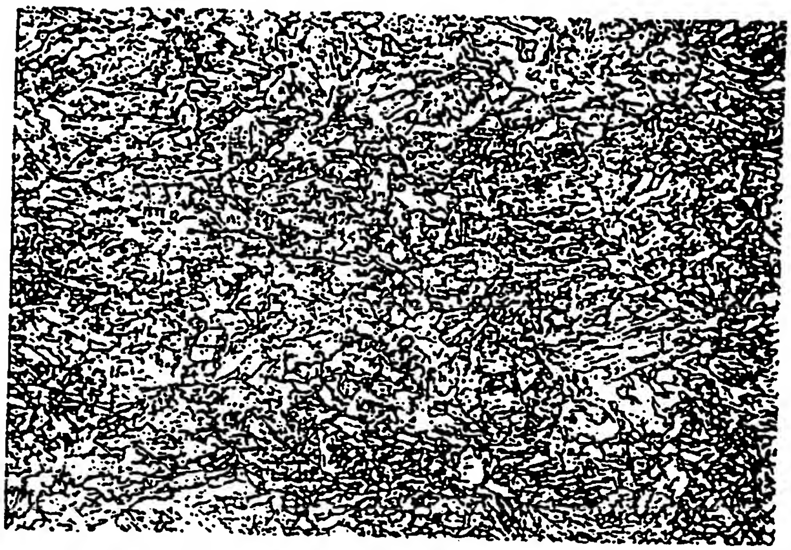

Effect of Molybdenum on Transverse Quarterthickness Strength and Toughness of RCR-IAC 1.5-inch-Thick Plates of Low-Carbon A852-Type Steel
Yield Strength, ksi
CVN Energy Absorption at 0° F, (ft-lb)
0
10
20
30
40
50
60
70
80
90
0.00
0.05
0.10
0.15
0.20
0.25
Molybdenum (%)
RCR-IAC 900° F YS
RCR-IAC 1100° F YS
RCR-IAC 900° F CVN @ 0° F
RCR-IAC 1100° F CVN @ 0° F

FIG. 1



Magnification = 400X
(Etched in 2 percent Nital)

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/15478

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C22C 38/22
US CL :148/334

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 148/334, 654

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 5,653,826 A (KOO et al.) 05 August 1997 (05.08.97), see entire document.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 AUGUST 1998	16 NOV 1998

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